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Influence of initial preferred orientations on strain localisation and fold patterns in non-linear viscous anisotropic materials

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Deformation localisation in rocks can lead to a variety of structures, such as shear zones and shear bands that can range from grain to crustal scale, from discrete and isolated zones to anastomosing networks. The heterogeneous strain field can furthermore result in a wide range of highly diverse fold geometries.

We present a series of numerical simulations of the simple-shear deformation of an intrinsically anisotropic non-linear viscous material with a single maximum crystal preferred orientation (CPO) in dextral simple shear. We use the Viscoplastic Full-Field Transform (VPFFT) crystal plasticity code (e.g. Lebensohn & Rollett, 2020) coupled with the modelling platform ELLE (http://elle.ws) to achieve very high strains. The VPFFT-approach simulates viscoplastic deformation by dislocation glide, taking into account the different available slip systems and their critical resolved shear stresses. The approach is well suited for strongly non-linear anisotropic materials (de Riese et al., 2019). We vary the anisotropic behaviour of the material from isotropic to highly anisotropic (according to the relative critical resolved shear stress required to activate the different slip systems), as well as the orientation of the initial single maximum orientation, which we vary from parallel to perpendicular to the shear plane. To visualize deformation structures, we use passive markers, for which we also systematically vary the initial orientation.

At relatively low strains the amount of strain rate localisation and resulting deformation structures highly depend on the initial single maximum orientation in the material in all anisotropic models. Three regimes can be recognised: distributed shear localisation, synthetic shear bands and antithetic shear bands. However, at very high strains localisation behaviour always tends to converge to a similar state, independent of the initial orientation of the anisotropy.

In rocks, shear localisation is often detected by the deflection and/or folding of layers, which may be parallel to the anisotropy (e.g. cleavage formed by aligned mica), or by deflection/deformation of passive layering, such as original sedimentary layers. The resulting fold patterns vary strongly, depending on the original orientation of layering relative to the deformation field. This can even result in misleading structures that seem to indicate the opposite sense of shear. Most distinct deformation structures tend to form when the layering is originally parallel to the shear plane.

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